10 RESEARCH, ENGINEERING, AND DEVELOPMENT

While numerous technologies employed during the early phases of NAS modernization are mature and well understood, many proposed possible paths for the later stages of modernization are just now emerging. Research, engineering, and development (R,E&D) activities will play a major role in assessing emerging technologies and discovering more advanced technologies that could be employed in modernization. This section describes the research efforts needed to fully understand and exploit the new and emerging technologies described in this architecture.

The FAA R,E&D program develops and validates technology, systems, designs, and procedures, along with supporting the agency's strategic requirements determination process. Today, the NAS is under heavy pressure to keep pace with rising traffic demand, needs for essential safety and security improvements, airspace user requirements for more flexible and efficient air traffic management operations, and demands for further mitigation of the environmental impacts of aircraft operations. As air travel increases, the agency's research and development work will take on added significance.

To meet these future challenges, the FAA employs a comprehensive, agencywide R,E&D investment analysis process to ensure that available resources remain customer-focused in terms of "outcomes" and "outputs," as mandated by the Government Performance and Results Act (GPRA) of 1993, and that these resources are targeted on the highest-priority activities.

The R,E&D program is divided functionally into seven areas. These areas are: Air Traffic Services, Airport Technology, Aircraft Safety, Human Factors and Aviation Medicine, Aviation Security, Environment and Energy, and R,E&D Program Management.

10.1 Air Traffic Services

The Air Traffic Services (ATS) R,E&D program is part of an integrated strategy intended to increase the scope and effectiveness of air traffic services at the most economical cost. ATS research is the agency's preferred means of leveraging its ATS investments for improved services, procedures, and infrastructure. ATS research integrates new concepts and technology, as required to meet demands for improved safety, efficiency, and productivity. The ATS RE&D programs yield operational concepts, human factors and performance guidance through simulation and analysis, standards for application of new technologies, prototype developments and evaluations, and software products for integration into current and future operational systems.

Listed below are the specific ATS research activities required for the modernization efforts detailed for each domain of this architecture (as described in Part III). The activities are identified by the appropriate modernization phases based on the time required to perform the activity and the completion date required to support enhancements to existing operations and deployment of future systems, as detailed in the NAS modernization schedule. As a result, this architecture represents a completely integrated program planning document depicting the most efficient and cost-effective approach to achieving the desired capabilities. If appropriate funding is not approved for R,E&D activity, there likely will be delays in the associated development schedule.

Currently, the FAA is reassessing the R,E&D program due to Congressional funding authorization actions. ATS services research is now funded by the facilities and equipment (F&E) budget. Although this will have some impact on the plan, the overall philosophy of the research activities that will be implemented out of F&E is consistent with the plan laid out here.

10.1.1 Navigation, Landing, and Lighting Systems

Phase 1 navigation and landing R,E&D will evaluate and develop the guidelines and procedures for the Global Navigation Satellite System/flight management system (GNSS/FMS) (or equivalent system) for precision arrival and departure paths. Standards, including minimum operational performance standards (MOPS) and technical standard orders (TSOs), will be developed for the Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) technologies to support their implementation into the NAS and to promote international acceptance.

Research will be conducted on the procedures, specifications, and design for a redundant system.

Other R,E&D activities will include investigating the use of security services to guarantee the availability and integrity of navigation services. As the ground-based very high frequency omnidirectional range (VOR) infrastructure is phased-down, a set of named grid points[1] will be established to replace the VOR and fix locations. R,E&D will look into developing a low-cost runway lighting system to support the expanded capabilities provided by satellite-based navigation.

Phase 2 research will investigate alternative satellite-based configurations for providing navigation services. It will also investigate an inexpensive ground-based navigation system for providing selected backup capabilities.

10.1.2 Surveillance

The goal of surveillance research is to extend surveillance, using satellite-based position reports, to nonradar and surface environments and to provide a more cost-efficient and safe surveillance service for the NAS. Services stemming from this research include extending surveillance to these environments to improve situational awareness of both service providers and flight crews, ensuring that this coverage includes all operating aircraft. The planning within the surveillance architecture indicates that automatic dependent surveillance (ADS) will evolve to be the principal surveillance reference and a key to NAS capacity enhancement.

In addition to demonstrating ADS technology during the Safe Flight 21 program, Phase 1 research will investigate the best means for integrating ADS into the NAS ground-based infrastructure and obtaining the operational benefits associated with ADS. Development of an ADS ground system design—including standards, procedures, and system-level specifications—will then proceed. As a means of improving target position accuracy, research will identify the types of data to be fused and how and when they will be fused—leading to the development of a system specification.

As surveillance systems evolve to provide greater accuracy, research will need to determine the benefits, procedures, and human factors impact of reducing separation standards.

Phase 2 research will define backup strategies—given that surveillance and navigation merge when using the Global Positioning System (GPS) as a source for both. The architecture requires and designates at least two complementary means of surveillance in each domain. This work will study alternative approaches and lead to the validation of a selected solution. Before the end of the useful service life of the airport surface detection equipment (ASDE)-3 surface surveillance radars, a research effort will support development of a low-cost strategy for tracking all vehicles on the active airport surface.

Future research will investigate alternatives for replacing the terminal radar/beacon systems, terminal Doppler weather radar (TDWR), and other terminal surveillance sensors with a single system, upgrades of a present system, or a different type of service.

10.1.3 Communications

The goal of communications research is to improve aviation-related information exchange between service providers and all users of the NAS with greater efficiency and at lower cost. This information exchange will be used to enhance situational awareness for both the flight deck and service providers in all domains. Based on the extensive use of data link envisioned for the future, specifications will be developed for communication links, message protocols, avionics requirements, and certification of service. Associated cost-benefit analyses will be completed. Data links will be developed to integrate the aircraft FMS capabilities with the ground-based decision support automation, which will allow more efficient operation of the aircraft and the air traffic control (ATC)/management system.

Phase 1 efforts will include human factors analysis that addresses the flight deck and ground systems associated with data link and the viability of operational procedure enhancements made possible by data link. Additionally, a communications

1. Named grid points will provide a common reference for fixed ground locations.

strategy with associated cost-benefit analysis will be developed to provide NAS-wide information service data to all interested parties for their use in operating within the NAS. Because the Agency has plans for increased access to more information, Phase 1 research must be conducted to develop information security strategies for interfacility, ground-ground, and air-ground communications. Communications research is also required to develop domestic and international digital signaling standards for current and future ATS voice switches.

In Phase 2, the availability of low earth-orbiting/ medium earth-orbiting (LEO/MEO) satellite networks will allow satellites to be used for new applications, with the cost of these services expected to decline. Research will investigate a satellite communications strategy for air-ground communications, including FAA-owned and -leased systems and GPS enhancements.

Alternatives and methodologies studies will be conducted for the aeronautical telecommunication network (ATN) to examine the system conditions required for optimal performance of each communications scheme, as well as the degree to which those conditions meet the requirements. The performance and capacity of the designed ATN will then be validated using actual data from an implemented integrated system. This validation will help ensure that, for strategic planning purposes, any ATC service provider can communicate with the flight deck of any aircraft, regardless of the aircraft's location.

Department of Defense (DOD) systems that incorporate the latest, most efficient, and effective technologies offer great potential for economically accommodating a variety of civil as well as military air-air and air-ground communications needs. The systems also demonstrate that continued cooperative FAA and DOD system development and procurement offer a clear way to avoid duplication of effort.

10.1.4 Avionics

To realize the full benefits of modernization, users must equip with new avionics. In Phase 1, research will examine the minimum avionics required—and the cost involved—to obtain various levels of NAS services. The program will develop recommendations for improving the avionics certification and testing process, including reengineering the certification process for efficient, affordable certification. Research efforts will study the development of standards, certification processes, and technology applications intended to lower the cost of avionics and improve safety and efficiency through higher levels of avionics capability and equipage for the general aviation (GA) community.

In conjunction with the Human Factors Research Program, research will investigate the human factors issues associated with using multifunction displays to support situational awareness. A major focus of human factors research will include assessing how to best use the limited panel space available and assess the effects of new avionics on single-pilot operations. Standards and procedures for pilot separation assurance in cases such as station-keeping over ocean and on final approach will be investigated.

A study will also examine the range of services provided to aircrews by automatic dependent surveillance broadcast (ADS-B), as well as related aircrew procedures. Avionics research goals include improving flight deck situational awareness through cockpit display of traffic information (CDTI) and providing timely information about weather, flight plans, predeparture clearances, and taxi path assignments. Flight deck utilization of automatic weather alerts and graphical weather data will be examined.

To support search and rescue efforts, a program will develop emergency locator transmitters (ELTs), which transmit aircraft identification and GPS-based position information.

Research will result in improvement or development of the following avionics services.

Navigation and landing enhancements include:

- Increased use of satellite-based radionavigation routings
- Implementation of additional FMS-guided procedures
- Location with reference to terrain obstacles and special use airspace (SUA)
- Taxi routes and position on the airport surface

- Landing guidance to broad areas (i.e., precision and nonprecision, decelerating, curved, and segmented precision approaches (for fixed wing and helicopters)).

Surveillance and user-supported separation enhancements include:

- Tracking of all vehicles on airport surface (ADS-B, infrared, etc.), based on performance impact assessment for controllers and/or pilots
- Position of all close-by aircraft
- Station-keeping in selected oceanic airspace to reduce separation standards and provide in-trail climb and in-trail descent
- Transfer separation assurance to the cockpit for some simultaneous approach operations
- Taxi routes and position on surface provided to and monitored on the flight deck
- Station-keeping on final approach.

Communications enhancements include:

- Data link capabilities on airport surface
- Predeparture clearances by data link
- Altitude, heading, and speed assignments; frequency and transponder code changes; and certain clearances provided by data link to aircraft
- Rerouting and clearance amendments
- Planning tools and digital negotiation capability for tactical and strategic replanning
- Access to weather data and ability to update flight preference in the flight object
- Performance and intent data automatically from onboard systems (i.e., FMS).

Weather enhancements include:

- Graphical weather display available to the cockpit
- Improved weather information from a common weather data base shared between NAS service providers and users
- Fully automated terminal information service (ATIS) and terminal weather advisories delivered by voice and data link
- Aircraft downlink of winds aloft, humidity, temperature, and turbulence.

Additionally, new areas of research will be investigated as experience is gained with new cockpit avionics and procedures.

10.1.5 Information Services for Collaboration and Information Sharing

Phase 1 research will support evaluation of information requirements for the operational concept and implementation of the NAS-wide information service and the flight object. Standards and procedures will be developed to support implementation of information services that will enable greater information sharing between NAS users, leading to increased collaboration and improved decisionmaking.

Phase 2 research will focus on information distribution and access, including large storage technologies, data warehouse technologies for real-time decision support combined with intelligent distribution, and search and access technologies in the object-oriented world. Research into seamless interoperability with data integrity built in is essential for one NAS-wide coherent homogeneous system of systems.

10.1.6 Traffic Flow Management

In Phase 1, research will focus on developing expanded methods for cooperatively managing demand capacity imbalances with the users.

In Phase 2, tools to support the real-time management of alternative airspace designs will be investigated. Additionally, the goal in Phase 2 is to develop information and tools that can be used at all levels of the traffic management system so that capacity constrictions can be identified and solved at the most appropriate level.

The Phase 3 research goal is to provide decision support system (DSS) tools to service providers, flight crews, and airline operations centers (AOCs) for strategic air-ground traffic flow management (TFM) collaborative decisionmaking (CDM) and problem resolution. Some tools could include 4-dimensional flow analysis and flight object identification. These tools will help ensure that any imposed flow restrictions are necessary and executed effectively. Improved methods for identifying and predicting dynamic density prob-

lems will be designed. Postflight analysis must provide users and service providers with information about NAS performance strategies to optimize future performance.

10.1.7 En Route

The goals of en route research are implementation of separation standards matched to the accuracy of the positional information available, to relieve frequency congestion, and provide conformance monitoring of the flight profile. Achieving these goals will allow a shift in controller workload and assist controllers in separating aircraft from weather, which will increase throughput in en route airspace. Throughput may also be increased by transferring separation assurance to the flight deck in certain situations and allowing more user-preferred trajectories to be flown. The research efforts that support the en route domain will focus on greater utilization of the aircraft flight data management system, continued access to expanded flight information, improved decision support tools, and enhancements of data link applications to send and receive data in a more intelligible form.

Phase 1 research will evaluate airspace design alternatives for reduced vertical separation while accounting for the need to accommodate non-equipped aircraft in the airspace. Decision support tools for 4-dimensional flight profiles, hazardous weather, and ADS intent data as well as improved trajectory design tools will be developed to enhance aircraft monitoring and conflict prediction. Research will investigate methods of more precise separation and flight progress monitoring and of dynamic route structuring adapted to flight-level winds, hazardous weather, airspace demand, and user preferences.

In Phase 2, research will be conducted to validate the concept of dynamic sectorization of airspace to best match controller and traffic workloads. With the move to data link, design concepts will be investigated to determine how altitude assignments, frequency changes, and limited numbers of clearances can best be provided. Supporting en route controllers with an enhanced conflict detection capability, decision support software will be designed to monitor an aircraft's conformance to its intended profile. Research efforts will also look at more effective means of displaying flight progress information and concepts for other backup modes of operation.

In Phase 3, research will evaluate the flight object to determine how its detailed flight plan and trajectory information can be utilized to provide additional benefits to users and service providers. An effort will be made to determine how to probe all flight profiles when major environmental changes occur and how to provide access to this information for the flight deck, AOCs, and service providers to facilitate the strategic replanning process. Tools that will recommend flight profile changes based on present and predicted environmental changes will be investigated. Additionally, research will look at how to evolve the oceanic, en route, and terminal domains into a consistent, seamless operational environment that provides more precise monitoring of separations and flight progress.

10.1.8 Oceanic

A primary goal of oceanic research is to investigate procedures and separation standards that are related to the ADS capability to provide position and intent information to controllers and users. Other R,E&D goals are to develop a reliable digital air-ground communications system, to investigate flight deck/controller workload issues, and to monitor aircraft conformance to planned route of flight. In Phase 2 and Phase 3, the oceanic and en route domains will evolve toward a consistent, seamless operational environment.

10.1.9 Terminal

The research goals are to provide DSS and automation tools that help controllers establish optimal runway assignments and efficient arrival and departure paths. The tools will also support digital communications to the flight deck, implementation of reduced separation standards (commensurate with improved surveillance), and flight plan conformance monitoring. Automation tools will be integrated across facilities for consistency in optimizing traffic flow. Collectively, these tools will enable the number of departure and arrival paths to be increased and allow for more efficient arrival trajectories, including providing wake vortex spacing.

Tools will be developed to support data link transmission of altitude assignments, frequency

changes, and certain clearances to aircraft. Research efforts will also investigate automated methods for controllers to coordinate gate and runway assignments with arriving aircraft in near real time.

Phase 1 research efforts will evaluate a streamlined method for designing and certifying arrival and departure routes. During Phase 2, research on integrating the automation decision support system to meet terminal and offshore requirements will determine the appropriate level and extent of integration. Information display techniques will then be developed to integrate surface, terminal, and wake vortex information into a simplified format to support departing and arriving traffic sequencing. Data link applications that support air-ground negotiation of arrival trajectories will be investigated. Phase 3 research on the integration of the automation decision support system to meet terminal and surface requirements will determine the appropriate level and extent of integration. Research efforts will also examine more effective means of displaying flight progress information and concepts for other backup modes of operation.

10.1.10 Tower

Tower-oriented research will provide decision support system tools and associated systems integrated with terminal automation tools. This research will support predeparture clearances by data link; real-time collaboration with terminal; dynamic planning of surface movement; better coordination of local operations based on arrival information and surface and departure schedules; surface and airborne surveillance information; and flight and weather information. This information will be provided to service providers, airline ramp operators, airport operators, and airport emergency center personnel.

10.1.11 Flight Services

The research goal in this domain is to develop decision support tools and associated systems for interactive preflight planning. The system will provide planners with information (such as NAS constraints, SUA status, and notices to airmen (NOTAMs)) and feedback about nonapproved segments of the proposed flight plan. The system will also propose alternatives so that a planner is able to select the optimum route. Capabilities improved by this research include interactive flight planning and reduction or restructuring of visual flight rules (VFR) flight plans (using the NAS-wide information service and the flight object).

The research will also investigate improvements to search and rescue capabilities using aircraft-transmitted ADS-B position and identification. Additionally, this capability will also incorporate data received from the newly developed ELT, which provides discrete identification codes and GPS-based position information (see Section 18, Avionics).

Phase 2 research efforts will enhance interactive flight planning and alternative route development decision support tools. It will also enhance search and rescue operation efficiency. Research will look at the design of compatible domestic and international flight plan/flight object formats to allow for increased preflight and in-flight information exchange among service providers and users.

Phase 3 research will develop the guidelines and specification for the detailed time-based trajectory flight profile that will replace the flight plan.

10.1.12 Aviation Weather

The aviation weather research program focuses on applied research and conducting limited basic research through collaboration with other federal and academic institutions. The program aims to generate more accurate and accessible weather observations, warnings, and forecasts that allow the FAA to solve operational problems. Research focuses on these areas:

In-Flight Icing. The goal is an hourly, gridded depiction or forecast of in-flight icing. Research on freezing drizzle and icing severity will continue.

Aviation Gridded Forecast System. This system mitigates communications bandwidth problems by transmitting the weather data as gridded data fields, which are smaller than large graphic files. Mesoscale models will use higher resolution grids and improved algorithms to provide refined, critical weather elements data—such as convection, icing, and turbulence—to the aircraft.

Weather Support to Deicing Decisionmaking (WSDDM). To optimize ground deicing opera-

tions, WSDDM software will produce an accurate graphical depiction of the real-time, 30-minute nowcast and a 4-hour forecast of precipitation intensity and type, weather condition, temperature, and wind speed for the 10-kilometer area around an airport.

Humidity and Turbulence. Sensors are installed on board commercial aircraft to obtain outside humidity data and algorithms that are added to the In-flight Management System to calculate turbulence. Humidity and turbulence data are then downlinked as part of the aircraft's normal air-ground communications. These increased and expanded data provide a new capability for National Weather Service (NWS) models, which improves forecasting. At the same time, these improved airborne data allow scientists to update the logic in the algorithms used in the weather processors. This data will be used to develop and test national-scale turbulence modeling efforts.

Convective Weather. Research is underway to improve convective weather forecasting to provide forecasts of storm cells. Forecasts range from short-term predictions of storm growth and decay (nowcasts) to longer-term predictions of convective storm activity. The goal is to improve today's forecasts from 30 minutes to 6 hours in advance.

Ceiling and Visibility. This research is aimed at providing short-term (up to 6 hours in advance) predictions of when the ceiling and/or visibility in a terminal area will allow routine instrument flight rules (IFR) operations to be resumed.

Model Development and Enhancement. This research effort focuses on improving the accuracy of numerical weather models that support aviation weather.

Wake Vortex. The primary objective of the FAA Wake Vortex program is to increase understanding of vortex behavior so that new wake vortex separation rules based on aircraft performance can be established to increase terminal capacity.

10.1.13 NAS-Wide Research, Engineering, and Development

Concept of operations (CONOPS) research is a cross-cutting activity that will be conducted to develop additional detail and to validate the CONOPS for the modernized NAS. Research will include identifying and validating task taxonomy, roles and responsibilities, information flows, and scenarios. Human-in-the-loop analyses of the scenarios associated with concepts that reassign tasks or roles and responsibilities will also be performed. Finally, fast-time simulations will be conducted to link human-in-the-loop results to NAS levels of traffic and complexity.

Evaluation and validation of the safety and environmental impacts associated with the CONOPS will be performed. The system modeling of the NAS and the CONOPS will be updated to improve operational performance analysis. This analysis will support all phases of operational and system development (i.e., concept development, concept validation, demonstration, and deployment). It will also significantly improve the economic assessment in the investment analysis process.

Research is required to support flexible airspace use and dynamic resectorization. Some factors that will be considered are use of analytic tools and development of performance measures for airspace utilization. Tools will be developed to evaluate airspace structure and sectorization during the day and to make adjustments as operational situations demand. Additional airspace considerations are to expand the oceanic and en route routing structures and make them flexible. In the terminal area, the goal is to expand the number of airport departure and arrival routes. Some research considerations are increased use of space-based navigation, late-descent flight profiles, and higher aircraft speeds when flying below 10,000 feet.

Research is required to establish operational infrastructure strategies based on availability and safety of services. The primary goal is to develop a fault-tolerant NAS design based on safety, risk, security, and economic analysis. Studies will be conducted to determine metrics for system safety and system performance parameters. Increased NAS automation will require studies to determine the proper level of information security.

A NAS software research and development program will investigate domain-specific software architecture to improve software reuse and reliability. The program will address software certifi-

cation, especially safety-critical systems that use commercial off-the-shelf software.

The R,E&D program will further review the expanded use of remote monitoring and maintenance control that will include CDM for prioritizing preventive and restorative maintenance activities.

R,E&D activities are needed to support security services in the future NAS. This is associated with developing and implementing new hardware and software functionality and related processing and information flows. Known security approaches may not scale well, or they may not be appropriate for the NAS's mixed government-private composition. R,E&D security activities must also address the security impacts of planned NAS work and define the necessary enhancements.

An additional requirement for the modernized NAS is to research innovative methods to support investment decisionmaking by the FAA. Because of the deregulated nature and the diversity of the user community, the traditional investment method of cost-benefit analysis is becoming increasingly ineffective. A strategy that reduces uncertainty by considering the complex nature of the NAS and the service role of the FAA is needed. A major consideration is the cost-effectiveness of user avionics and the cost of the decision support systems required to support the CDM capability of the automated NAS infrastructure.

To contribute to the development and implementation of the 2005 NAS CONOPS and its supporting architecture, human factors research will be addressing issues implicit in the design of new systems and procedures. Research in this area will define changes to operational concepts, and human factors research will provide information concerning the feasibility of these operational changes.

The research and development activities regarding separation standards and assurance will contribute to safe separation of air traffic. The primary goal of separation standards research is to provide decisionmakers with quantitative guidance for establishing and maintaining safe separation standards. The secondary goal of this research is to provide decisionmakers with tools to assess the value of changing separation standards. Methodologies will be developed to determine minimum safe separation criteria. The process will account for the performance of situational awareness systems, such as navigation, communication, surveillance, and decision support systems. Additionally, operational factors such as traffic flows, ATC, and cockpit human factors will be accommodated, and uncontrollable influences such as weather and in-flight emergencies will have to be considered.

Research will consider the adaptation of international standards for reducing vertical separation to 1,000 feet between aircraft flying above 29,000 feet. Additional research will be needed to develop the requirements for transferring safe separation assurance responsibility from ATC to the cockpit under certain situations. The benefits and costs of reducing or changing separation standards also need to be assessed.

10.2 Airports Technology

The Airports Technology R,E&D mission is to provide solutions that will allow the nation's airports to accommodate the projected traffic growth cost-effectively and safely. See Section 11, Regulation and Certification Activities Affected by New NAS Architecture Capabilities, for more details.

Airport technology R,E&D programs develop new standards and criteria for airport planning, design, construction, operation, and maintenance. Research into visual guidance systems will enhance airport ground operations at night and during low-visibility conditions. Improvements in airport lighting, signs, and markings will help eliminate runway incursions. Airport research includes:

- Airport planning and design research, which produces aircraft/terminal compatibility analyses, design standards for terminals, design standards for multiple/parallel runways, and user guides for airport operators and industry
- Airport pavement technology research, which provides 3-dimensional, finite element models for airport pavement design, national pavement test machine, and data base of in situ airport pavement performance
- Airport safety technology research, which provides technical data supporting runway

maintenance regulations and advisory circulars; design specifications for fire training facilities; design criteria for airport, heliport, and vertiport lighting and markings; technical data on firefighting agents and vehicles; and technical data and advisory circulars on wildlife habitat management, bird harassment techniques, and landfills.

10.3 Aircraft Safety

R,E&D includes research in a wide range of areas related to the safety of aircraft, crew, and passengers. The R,E&D program develops technology, technical information, tools, standards, and practices to ensure the safe operation of the civil aircraft fleet within a safe global air transportation system. The program focuses on eliminating hazards to a safe air transportation system, both to prevent accidents and to mitigate the effects of any accidents that do occur. See Section 32, FAA Regulatory Mission, for more details.

Aircraft safety R,E&D programs develop new technologies to improve NAS safety and provide the FAA's Regulation and Certification organization (AVR) with the necessary information to carry out its mission. These programs address the many hazards that face all aircraft, as well as special hazards endemic to certain segments of the civil aircraft fleet. For example, older aircraft are susceptible to structural problems caused by metal fatigue and corrosion; newer aircraft, with digital flight controls and imbedded software, are susceptible to electromagnetic interference. The major aircraft safety programs include:

- Aviation safety risk analysis, which has resulted in the safety performance analysis system and the system for identifying aircraft certification risks
- Fire research and safety, which has led to requirements for non-halon fire-extinguishing agents, fire-hardened fuselage structures, fire-safe emergency oxygen systems, fire-resistant materials for cabin interiors, and cabin safety/benefit analysis models
- Advanced material/structure safety research, which is responsible for the handbooks on composite technologies and manufacturing/inspection analysis techniques, data packages on certification of structures made from advanced materials and on seat restraint systems, and technical data on crash-resistant auxiliary fuel system designs
- Propulsion and fuel systems work that has resulted in probabilistic engine rotor design code, specifications for titanium alloys, and certification standards for unleaded fuels
- Flight safety/atmospheric hazards research that led to aircraft surface-ice detection technologies and systems, electronic threat definition and validation, and technical data on digital technology for flight-critical systems
- Aging aircraft program work that has enabled the development of analytical tools and models to assess commuter and transport aircraft structural integrity and repairs.

Human factors research is used to improve:

- Systems design
- Certification and regulation decisions
- Operating directives
- Training procedures.

Human performance remains a critical part of safe and efficient NAS operations. Advances in technology have increased the reliability of most NAS components; however, the number of accidents and incidents attributed to human error has remained constant. AVR's human factors programs support the National Plan for Civil Aviation Human Factors by addressing priority areas such as aircrew performance, aircraft maintenance, and aircraft cabin environment. Human factors research includes:

- Research into the flight deck and aircraft maintenance areas that led to the development of human factors guidelines to reduce automation-related errors
- Flight deck/ATC system integration work that resulted in human factors guidelines for computer-human interface applications and the ability to assess human performance in a highly integrated/automated environment
- Aeromedical research that led to quantitative bioengineering criteria for aircraft evacua-

tion, flotation devices, and other rescue equipment.

10.4 Human Factors and Aviation Medicine

The Human Factors and Aviation Medicine program identifies methods that help reduce the fatal accident rate; ensures human factors issues are addressed in the acquisition and integration of FAA aviation systems; and develops recommendations for protective equipment, procedures, standards, and regulations to protect all aircraft cabin occupants. Human factors research will increase NAS safety and efficiency by developing scientifically validated information and guidance for improving the performance and productivity of air traffic controllers and NAS system maintenance technicians. The Human Factors program addresses operational requirements through research in the areas of Human-Centered Automation, Selection and Training, Human Performance Assessment, Information Management and Display, and Bioaeronautics. For more details, see Sections 8, 15 through 27, and 32.

10.5 Aviation Physical Security

The main goal of the Aviation Security program is to mitigate the terrorist threat to the civil aviation system. Through the Aviation Security R,E&D program, the FAA promotes development of technologically improved products in explosive detection, aircraft hardening, airport security, and human factors. Products from the R,E&D program include explosive detection systems and devices, technologies, specifications, and technology integration plans. See Section 32 for more details.

Civil aviation security is focused on countering increasingly sophisticated threats to civil aviation. The spread of terrorism makes it imperative that the FAA develop effective countermeasures. Emphasis is on developing automated capabilities to prevent explosives from being carried onto aircraft and on enhancing human performance. Research also includes devising test protocols and performance criteria for automated explosives detection systems. Civil aviation research includes:

- Explosives/weapons detection research that has developed trace and bulk personnel screening portals and certification of trace electronics screening systems
- Aircraft hardening research that provides guidelines for blast mitigation/aircraft hardening, design specifications for aircraft and support equipment, and threat assessments on advanced terrorist weapons
- Airport security technology research that provides airport vulnerability reports and analytic models for threat, risk, and vulnerability assessment
- Aviation security human factors research that produces human systems integration analyses, reports on explosives and weapons detection technologies, and automated profiling systems.

10.6 Environment and Energy

The Environment and Energy R,E&D program identifies, controls, and mitigates environmental consequences of aviation activity. The program is composed of three major disciplines, including aircraft noise reduction and control, engine emissions reduction and control, and aviation environmental analysis. These disciplines form a cohesive focus of research projects to support federal actions regarding noise and engine exhaust emissions. See Section 30 for more details.

10.7 Program Management

The Program Management R,E&D program provides for effective and responsible stewardship of funds entrusted to the FAA for research and development by NAS users. Effective stewardship of the R,E&D program requires that NAS users receive the best possible program for their investment. Participants ensure that the correct research is performed, the necessary provisions are made in the budget and planning process, and the highest standards of financial accountability are rigorously maintained.

Additionally, the program must fund no research that duplicates work being performed elsewhere, particularly with National Aeronautical and Space Administration (NASA) funding. The FAA has and will continue to work with other agencies, including NASA and DOD, to leverage research dollars in the search for common solutions to problems affecting aviation.

10.8 Summary

Understanding what role new and emerging technologies play in NAS modernization and how to best adapt these technologies to increase NAS efficiency and safety are key elements in implementing this architecture. Working with industry and other government agencies, the FAA will leverage scarce resources to maximize potential benefits.

The transition of research funding from R,E&D to F&E appropriations has created a direct linkage between research and capital investment. Much of the research identified in the *National Airspace Architecture Version 4.0* will need to rely on funding by public/private partnerships, industry investment, and the developing consensus on the role and funding level for research within the FAA and NASA on aviation research.